Projected Changes in Nile Flows Using RCM Models and NFS Hydrological Models

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Beirut (26-28) June 2013
Modeling Climate Change Impacts
Methodology and Uncertainty Cascade

Emissions → Concentrations → Radiative Forcing → Global Climate Models → Regional Details (Downscaling) → Impact Models (e.g. Hydrology)

Observations

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The Nile Basin

- Large area \((2.9 \times 10^6 \text{ km}^2)\)
- Low specific discharge
- Spans several climate regions
- Variable topography
- High runoff variability
- High Sensitivity to Climate
Previous Studies (1)

Lake Nasser Flood & Drought Control Project (2008)

- 6 Transient scenarios (3 GCMs x 2 Emission Scenarios)
- Statistically downscaled using a spatio-temporal weather generator
- Changes at Dongola from 2010-2100
Elshamy et al. (2009)

- 17 GCMs x A1B scenario
- Statistically downscaled using Bias Correction Method
- Blue Nile Flow Changes: -60% to +45%
Coarse Scale GCM Boundary Conditions

RCM Downscaling

Fine-Scale Climate (Baseline 1950-2000 & Future 2020-2050)

Calculate Delta Change Factors (DCFs)

Modify Baseline Data (1989-2007) using DCFs

Determine Hydrological Impacts (NFS)
• Higher Resolution: Better Representation of shoreline and terrain

• Physical Model: Consistent Climate Elements
Methodology: Ensemble Selection

Emission Scenario A1B

- Ensemble of 17 transient GCM runs (1950-2050)
- West Africa precipitation skill
- East Africa precipitation skill
- Indian monsoon skill
- Nile basin temperature skill
- Ranked list of runs
- Even selection to explore the spread
- ens. member 1
- ens. member 5
- ens. member 9
- ens. member 13
- ens. member 17
- RCM1
- RCM2
- RCM3
- RCM4
- RCM5

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Results: Rainfall Changes - Ratios

<table>
<thead>
<tr>
<th>Jan</th>
</tr>
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<tbody>
<tr>
<td>Mean 1.10863</td>
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Off Scale (>3)
Black  Ratio cannot be calculated
Results: Rainfall Changes - Ratios

Mean 1.10793
Max 2.88138
Min 0.188871

Off Scale (>3)
Black Ratio cannot be calculated

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Results: Temperature Changes - Diffs

Mean 1.57074
Max 3.16746
Min 0.459253
Results: Temperature Changes - Diffs

Mean 1.89223
Max 4.88084
Min 0.218916

Aug
Results: PET Changes

NFS

Selected Scenario
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NFS System

- Rain gauge Data
- Satellite Images

Rainfall Estimation Models

Rainfall Estimates

Hydrological Models

Simulation and Extended Stream Flow Prediction (ESP)

- Water Balance
  - Hill Slope
  - Routing
  - Swamp
  - Lake

- Historical Climate
  - GIS
The NFS is a spatially distributed grid-based system consisting of three model components:

**Water Balance Model:** simulates the production of surface and subsurface runoff and allows for continuous soil water accounting.

**Hill Slope Model:** transforms the combined surface and subsurface runoff into channel inflow hydrograph for each grid cell.

**Channel Routing Model:** carries the flow downstream within the channel network.
Preparation of climate change input data for NFS

- Multiplicative change factors for rainfall were used to modify present NFS daily rainfall time series for the period 1989-2007 and consequently generate perturbed time series representative of future conditions.
- Potential evapotranspiration (PET) for each of the ensemble members was calculated using the Penman-Monteith method (Allen et al., 1998) using RCM outputs of temperature, humidity, surface wind speed, and shortwave radiation. Performed on a monthly for baseline and future periods and then the resulting used to derive DCFs for PET.
- The NFS was run using the modified rainfall and PET inputs while all other factors are kept fixed (e.g. Sudan abstractions, operation of the man-made reservoirs of Sennar, Roseries, and Gabal Al-Awlia).
- The estimates of Nile runoff were then compared with those predicted by NFS under present day conditions (baseline simulation) to determine the impact of climate change on the flow at key locations along the river.
Hydrological Changes: Blue Nile@Diem

Map of the Nile River Basin showing countries and regions such as Egypt, Sudan, and Ethiopia.

Graph showing monthly flow changes from January to December with different lines representing various flow conditions.

Graph showing rainfall changes with lines representing different months.

Graph showing PET (Potential Evapotranspiration) changes with lines representing different months.
Hydrological Changes: White Nile@Malakal
Hydrological Changes: Main Nile @ Dongola
Summary of the Results

- Expected ranges for changes in rainfall, temperature, and PET are smaller than previous studies
- Changes in flows:
  - -19% to +29% for the Blue Nile (Diem)
  - -8% to +10% for the White Nile (Malakal)
  - -13% to +36% for the Whole Nile (Dongola)
- RCM provides a viable downscaling methodology
- RCM results confirm the uncertainty regarding the direction of change for rainfall and flow
- RCM reduced the uncertainty bandwidth but care must be taken that not all sources are included
Thank You

Doaa Amin
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Rainfall Estimation Techniques

Satellite Estimates

Gauge Estimates

Merged Estimates

Synop Data
Today's Soil/Canal Conditions

Historical Rainfall (60 Years)

Hydrologic Simulation Model

ESP + Probability Distribution Function

Hydrograph Plot for Dongala

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BASIC Theory

It has two layers:

Upper layer: Shallow, Fast Flowing

Bottom Layer: Deeper, Store a lot of water

The Outflow is the total runoff (in mm) which is a combination of:

The surface and sub surface runoff

Fig. (3)
Each pixel is like a small watershed and may contain several small channels and hillslopes.
EFFECT: SERIES OF CASCADING STORAGE CELLS.